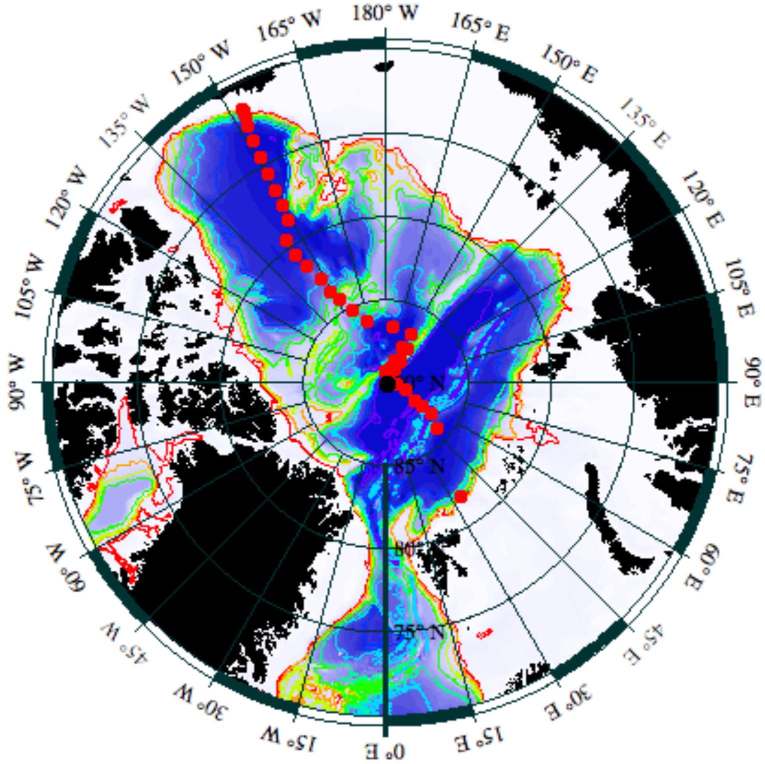
CRUISE REPORT: ODEN05
(Updated FEB 2010)



A.   HIGHLIGHTS

CRUISE SUMMARY INFORMATION

Section designation	**ODEN05**
Expedition designation (ExpoCodes)	**77DN20050819**
Chief Scientists	**Anders Karlqvist/SPRS**
Dates	2005 AUG 20 – 2005 SEP 25
Ship	*R/V ODEN*
Ports of call	Barrow, Alaska to Longyearbyen, Spitsbergen
Stations	48
Geographic boundaries	89° 59.2 N 173° 51.67 W 174° 13.32 E 71° 23.08 N
Floats and drifters deployed	0
Moorings deployed or recovered	0

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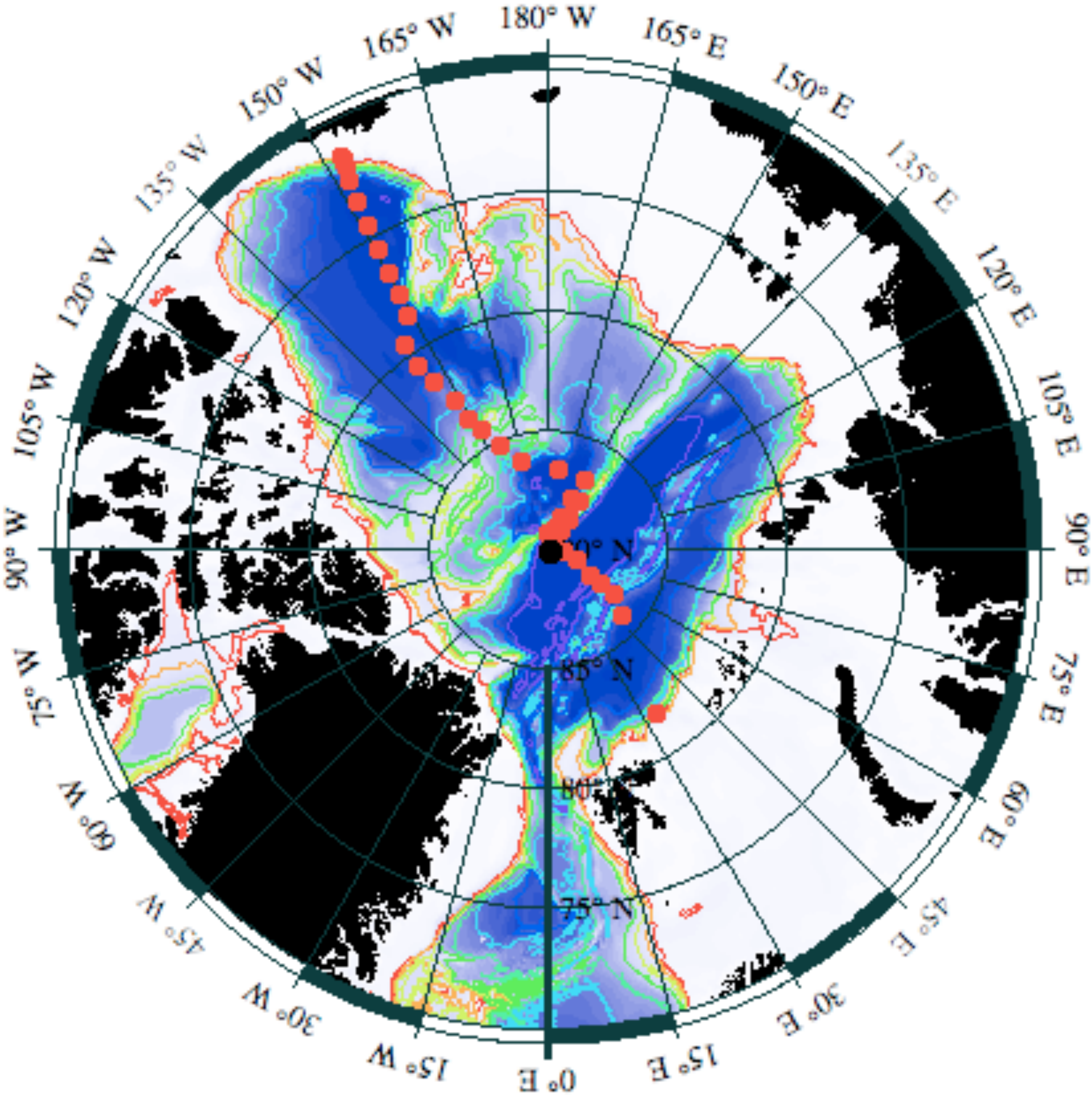
LINKS TO TEXT LOCATIONS

Shaded sections are not relevant to this cruise or were not available when this report was compiled

Station Locations • ODEN05 • 2005 • Karlqvist • R/V Oden



Summary

A hydrographic survey of the Arctic Ocean was carried out from the Swedish IceBreaker Oden between Barrow, Alaska and Longyearbyen, Spitsbergen. The expedition departed Barrow on 19 August 2005, then completed a transect of the Canada Basin. The Oden joined forces with the USCGC Healy near the end of that transect, then surveyed the Lomonosov Ridge area. The ships reached the North Pole on September 12, then continued across the Amundsen Basin to the Gakkel Ridge and the Nansen Basin. The cruise ended in Longyearbyen on 25 September 2005.

xx full-depth CTD/rosette/LADCP casts and xx shallow rosette casts were completed during the cruise. xx microstructure casts were also done, and multiple ice stations for ancillary programs were occupied during the expedition.

Salinity, dissolved oxygen, and nutrients were analyzed for up to 36 water samples from each cast of the principal CTD/rosette program. Other parameters sampled and analyzed on-board included chloro-fluorocarbons, halocarbons, dissolved inorganic carbon, total alkalinity, pH, sulfur hexafluoride and mercury. Other samples were collected for later analysis for Helium/tritium/radiocarbons, several other radiochemicals, dissolved organic matter and several biology programs.

Introduction

A sea-going science team from multiple oceanographic institutions in Europe, Canada and the United States participated in this expedition. Several other science programs were supported with no dedicated cruise participant. The major programs, plus the on-board science team and their responsibilities, are listed below.

Principal Programs

Analysis	Institution	Principal Investigator
CTDO/S/O_2/Nutrients	UCSD/SIO	James H. Swift
Halocarbons/Biology	Chalmers University	Katarina Abrahamsson
CFC	BIO	Peter Jones
$^3He/^3H/\delta^{18}O/^{14}C$	LDEO	Peter Schlosser
Mercury	Göteborg University	O. Lindqvist
DIC/TAlk/pH/SF_6	Göteborg University	Leif Anderson
^{129}I	Univ.Pierre et Marie Curie	Jean-Claude Gascard
DOM/Triple-O/Haardt Fluorometer	TAMU-Galveston	Rainer Amon
POP/Muir	NILU	Henrik Kylin
^{226}Ra	Univ.of Quebec Montreal	Sandrine Solignac
Animal Ecology	Lund University	Thomas Alerstam
Atmospheric & Bio Optics	Eotvos Univ. Budapest	Gabor Horvath
Bird Navigation	Lund University	Susanne Åkesson
Microstructure/LADCP/Floats	WHOI	Peter Winsor
XBTs	IfM-U.Hamburg/WHOI	Detlef Quadfasel/Peter Winsor

Principal Programs of AOS-2005

Personnel

Shipboard Duties	Name	Affiliation	email
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Scientific Personnel AOS-2005

Narrative

The Healy – Oden Transarctic Expedition (HOTRAX)
The Baltic Sea Protal http://www.itameriportaali.fi/en_GB/
BERT RUDELS AND MAIJU LOIVULA, 5.6.2006

The 19th of August 2005, 2 days behind schedule, the Swedish icebreaker Oden anchored off Barrow, Alaska for exchange of crew and scientists before starting the third leg of the Beringa – 05 expedition. Oden had already in late June left Göteborg, crossed the North Atlantic and passed through the Northwest Passage into the Arctic Ocean. Now the fieldwork in the Beringia region was completed and the return voyage across the Arctic Ocean could start. The waiting scientists, mostly oceanographers but also ice researchers and biologists, had flown with a Swedish air force C-130 (Hercules) from Stockholm via Longyearbyen and Fairbanks to Barrow and were brought onto the ship by helicopter, one Alaskan helicopter and one brought from Sweden inside the Hercules. At 6 am on the 20th of August Oden weighed anchor and sailed towards the Canada Basin and the first oceanographic station.

The oceanography programme on Oden was a joint effort involving scientists from Sweden, Canada, Finland, France, Germany and the United States. Its overarching objective was to study the role of the Arctic Ocean in the global climate system. An important part of the programme was to determine the distribution, circulation and transformation of the different water masses in the Arctic Ocean – the Atlantic water advected into the Arctic Ocean via Fram Strait and the Barents Sea, the Pacific water entering through Bering Strait, as well as the waters formed within the Arctic Ocean: the polar mixed layer, the halocline and the different deep waters. One aim was to discover how much the waters formed in the Arctic Ocean contribute to the global thermohaline circulation. These studies require information about the distribution of salinity, temperature and other parameters in the water columns. Salinity and temperature are measured throughout the water column by continuously recording CTDs (conductivity-salinity-depth), while other parameters demand water sampling and analyses onboard and perhaps also in laboratories on land.

The initial plan was that Oden should take the first complete synoptic hydrographic section across the 4 major basins of the Arctic Ocean, the Canada Basin, the Makarov Basin, the Amundsen Basin and the Nansen Basin. At the Alpha-Mendeleyev Ridge between the Canada and Makarov basins a meeting was planned with the US coastguard cutter Healy, who was conducting mainly geological and geophysical studies of the sea floor. During the rest of the cruise the two ship were to work together, completing the HOTRAX transect, Oden assisting Healy when she was running seismic, and Healy's side-scan echo sounder helping to find the deepest passage across the Lomonosov Ridge, where Oden were to study the exchange of deep waters between the Makarov and Amundsen basins. Above all, the presence of a second icebreaker instilled a sense of security, should the ice conditions become extreme or should an engine breakdown occur.

The ice conditions cruise were hard and the progress was slow through most of the Canada Basin. After some initial problem with the winch the CTD stations and the water sampling could nevertheless proceed according to plan. The meeting with the US icebreaker Healy was, however, delayed and the two ships met at the Alpha – Mendeleyev Ridge on the 31st of August, two days later than expected. Here the ice conditions were somewhat easier and both seismic studies and coring from Healy and hydrography casts from Oden could be carried out as the two ships proceeded together.'

Due to misunderstandings from the side of the manufacturer of XBTs (expendable bathythermographs) _ of the probes to be used to obtain a fine scale temperature section across the Arctic Ocean was not delivered in Barrow on time. The XBT programme was then changed to mainly cover the Canada Basin. After the rendezvous it was found possible to obtain additional XBTs from Healy, and a second XBT section across the Nansen Basin and the boundary current entering through Fram Strait could be planned.

The ice conditions in the Makarov Basin worsened gradually and the sailing was eventually restricted to the directions of the major leads. The ships were forced towards the west, around the deeper part of the Makarov Basin. Not until near the Lomonosov Ridge did the icebreakers turned northward into the deeper part of the Makarov Basin. One short CTD section was then taken from the deep basin to the crest of the Lomonosov Ridge.

Oden and Healy continued to a depression, or sub-basin, in the central Lomonosov Ridge to study the bathymetric features of the sub-basin and to examine if an exchange of deep water from the Amundsen Basin to the Makarov Basin took place there. The ice was fairly light and after a side-scan survey of the sill of the sub-basin towards the Makarov Basin had been made the two ships could work independently. Oden made several CTD casts to study the water masses in the sub-basin and at the sill to the Makarov Basin. As the ships attempted to leave the Lomonosov Ridge the ice again was heavier and they could not enter the Amundsen Basin on a direct course towards the North Pole. The ships had to move along the ridge towards Greenland and leave the ridge on the Greenland side of the entrance from the Amundsen Basin to the sub-basin in the ridge.

The two ships reached the North Pole on the 13th of September, later than any previous ship. This was subsequently found to be almost too late in the season. Once the sun is gone, winter rules. The ice conditions in the Amundsen Basin and over the Gakkel Ridge gradually became more difficult, but a reduced number of stations could still be taken. After the Gakkel Ridge the ice conditions were much worse and the time schedule could no longer be assessed. The two captains then decided to inhibit the station work to avoid unrepairable delays. The Nansen Basin was crossed at a speed of 1-2 knots and only the second XBT section, extending across the front between recirculating Atlantic water in the northern Nansen Basin and the boundary current entering through Fram Strait, was taken as the ship fought their way through the ice. When Oden and Healy finally got out of the ice, a last CTD station was occupied at the continental slope north of Nordaustlandet. The ships parted and Oden sailed for Longyearbyen, where the scientists left the ship.

Some preliminary results

The low salinity Polar surface water, originating from the Siberian shelf seas and the runoff from the Siberian rivers, which during the years in the 1990s with strong positive North Atlantic Oscillation (NAO) index (the difference in sea level pressure between the Azores and Iceland) had been forced into the Makarov and Canada Basin had now returned to the Amundsen Basin. The low salinity surface water separates the ice cover from the heat residing in the sub surface warmer Atlantic layer and its presence protects the ice from heat flux from below, which otherwise could affect its thickness.

The extended pulse of warm Atlantic water that in the early 1990s was observed to enter the Arctic Ocean and spread along the Siberian continental slope had now reached the southern Canada Basin. It had also penetrated from the Chukchi Cap into the northern Canada Basin, while colder and older, Atlantic water from the southern Canada Basin had been displaced northward along the American continental slope and entered the northern Canada Basin from the American side along the Alpha Ridge. In the Makarov Basin the warm pulse had recirculated around the basin, first along the Mendeleyev and Alpha ridges to the American slope and then back towards Siberia along the Lomonosov Ridge. By contrast the warm Atlantic water had now left the Amundsen Basin and been replaced by a colder Atlantic inflow making the maximum temperature of the Atlantic water on Amundsen Basin side of the Lomonosov Ridge equal to that on the Makarov Basin side. That the water moved in different directions on the two sides of the ridge was nevertheless evident by the presence in the Amundsen Basin of less saline and colder intermediate layer, originating from the Barents Sea inflow branch below the Atlantic water. Over the Gakkel Ridge the temperature of the Atlantic water again increased, signalling a recirculation of a new pulse of warm Atlantic water towards Fram Strait. At the last station, taken at the continental slope northeast of Svalbard still warmer and more saline Atlantic water was observed, indicating another pulse of warm Atlantic water entering the Arctic Ocean through Fram Strait.

The study of the deeper passage in the Lomonosov Ridge showed, not the expected inflow of colder Amundsen Basin water into the Makarov Basin, but a flow of warmer and more saline Makarov Basin deep (2000m) water into the Amundsen Basin. This inflow, not earlier observed, continued along the ridge towards Greenland, but it is likely to contribute to the mid-depth (1700m) salinity maximum present in most of the Amundsen Basin. Whether an overflow of Amundsen Basin water occurs elsewhere or only happens intermittently remains so far unknown.

The Oden and Healy expeditions were organised and mainly supported by the Swedish Polar Secretariat and by the US National Science Foundation. The participation of FIMR was partly supported by the Academy of Finland.

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

The basic CTD/hydrographic measurements consisted of salinity, dissolved oxygen and nutrient measurements made from water samples taken on CTD/rosette casts, plus pressure, temperature, salinity, dissolved oxygen, transmissometer, Seapoint fluorometer and Haardt fluorometer from CTD profiles. A total of 48 CTD/rosette casts were made, usually to within 5-10 meters of the bottom. No major problems were encountered during the operation. The distribution of samples is illustrated in figures 1.0 and 1.1.

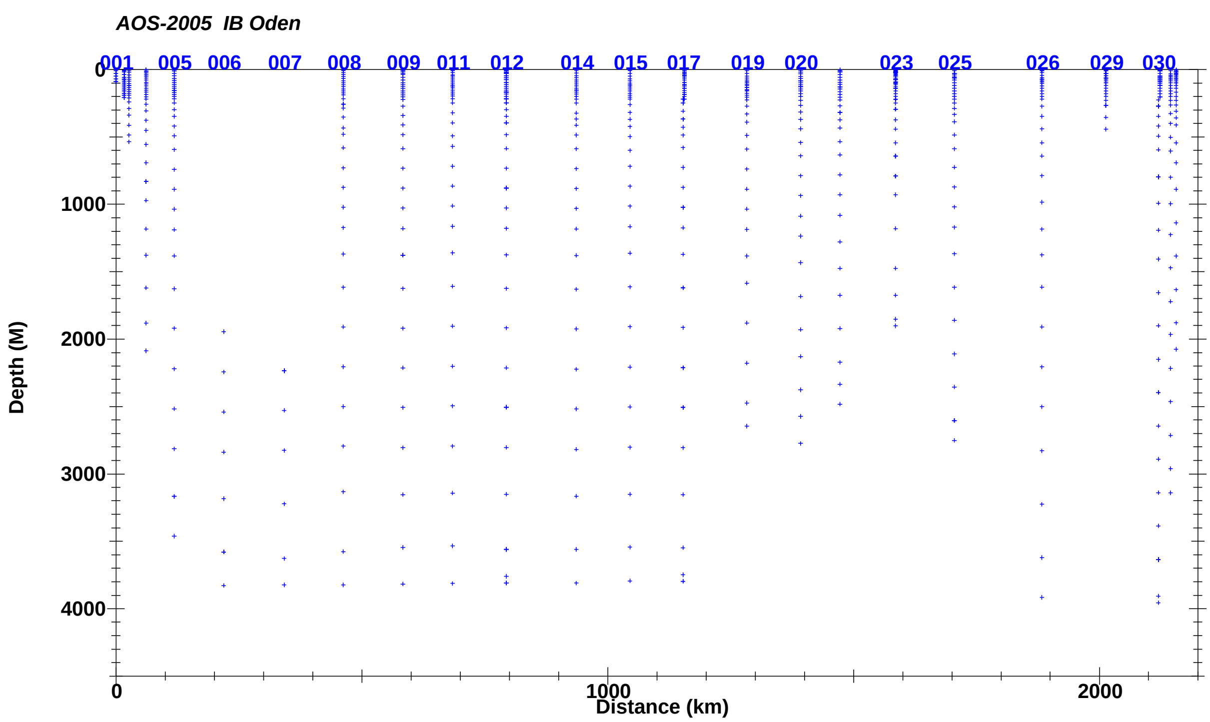

Figure 1.0 Sample distribution, stations 1-32 (Canadian Basin).

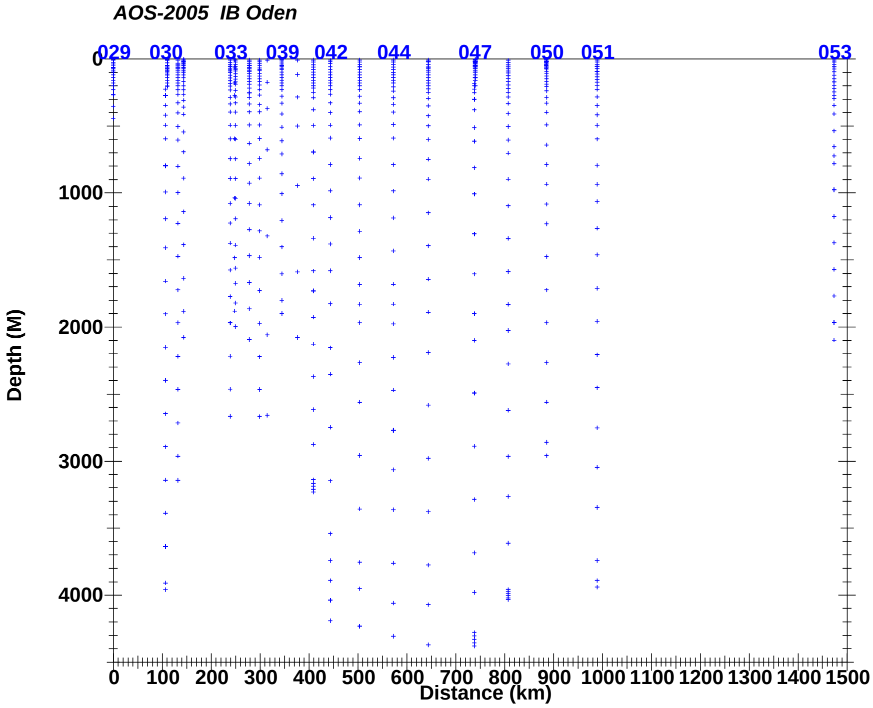

Figure 1.1 Sample distribution, stations 29-53.

1.1. Water Sampling Package

LADCP/CTD/rosette casts were performed with a package consisting of a 36-bottle rosette frame (STS), a 36-place pylon (SBE32) and 36 10-liter Bullister bottles (STS). Underwater electronic components consisted of a Sea-Bird Electronics (SBE) 9*plus* CTD (STS #381) with dual pumps, dual temperature (SBE3*plus*), dual conductivity (SBE4C), dissolved oxygen (SBE43), transmissometer (Wetlabs 25cm C-Star) and two fluorometers (Seapoint/chlorophyll a and Haardt/CDOM); an SBE35RT Digital Reversing Thermometer; an RDI LADCP (Workhorse 150kHz) and an altimeter (Simrad 807 or Benthos 916D).

The CTD electronics unit, with pressure sensor at the bottom, was mounted vertically in an SBE CTD frame attached to the bottom center of the rosette frame. Both pairs of SBE4C conductivity and SBE3*plus* temperature sensors and their respective pumps were mounted vertically as recommended by SBE. The SBE43 dissolved oxygen sensor was attached to the rosette frame and plumbed into the primary side between the conductivity sensor and pump. Pump discharges were attached to the outside corners of the CTD cage and plumbed to terminate at the same height and orientation as the T/C duct. The entire cage assembly was then mounted on the bottom cross-bracing of the rosette frame, offset from center to accommodate the LADCP lower head, and also secured to frame struts at the top. The SBE35RT temperature sensor was mounted vertically and equidistant between the primary and secondary T/C intake ducts. The altimeter was mounted on the inside of a support strut adjacent to the bottom frame ring. The transmissometer and fluorometers were mounted horizontally along the rosette frame adjacent to the CTD. The LADCP lower head was vertically mounted inside the bottle ring on the opposite side of the frame from the CTD. The upper head was mounted above the operating height of the bottle. Physical constraints required the head to be directly above the bottles.

The rosette system was suspended from a purposely built 2-32 P2 XXS 6000m two-conductor coaxial 8.15mm cable. The center 7-strand 20 AWG conductor was used for signal and power. The outer coaxially wrapped 15 AWG conductor was used for signal and power return. The double lay armor served only as the strength member.

The IB Oden's bow-mounted Seaproof Solutions winch was used for all Rosette casts. Electrical retermination was done twice between August 21-23 (after stations 6 and 7) while troubleshooting intermittent power/signal problems. The problem was finally traced to faulty sliprings, when shorting of the center conductor to ground remained after cast recovery. Sliprings were replaced with a spare set supplied with the winch.

Each bottle on the rosette was assigned a unique number, 1-36. These bottle numbers were maintained independently of the bottle position on the rosette and were used for sample identification. A unique "BIO" number sticker was attached to each bottle before cast deployment. A number was used exactly once, to identify a unique station-cast-bottle combination. No bottles were replaced on this cruise, although various parts on bottles were occasionally changed or repaired.

The deck watch prepared the rosette 10-20 minutes prior to each cast. For this cruise, sample spigots were replaced with 1/4" PVC ball valves to facilitate CFC gas sampling requirements. All valves, vents and lanyards were checked for proper orientation. The bottles were cocked and all hardware and connections rechecked. Once stopped on station, the LADCP was turned on. As directed by the deck watch leader, the CTD was powered-up and the data acquisition system started. Once the bow wash system was turned ON and the sea area forward of the bow was clear of ice, the rosette was moved into position on the bow beneath the A-frame. During below freezing deployments, warm saltwater was continuously passed over the sensors until the package was suspended 1.5m above the deck; then the tubing was removed and the package lowered expeditiously into the water. The winch was remotely controlled from the deck while the A-frame operator telescoped the package up and over the 1.6m rail, then down 6m to the sea surface.

The package was lowered to 10-15 meters below the surface until sensors equilibrated. Once the package was in the water, the A-frame telescope was retracted to bring the wire closer to the hull for protection against ice. The winch operator retired to the control area of the CTD container, by the console operator. When readings stabilized after the pumps turned on, the CTD console operator directed the winch operator to bring the package close to the surface, pause for typically 10 seconds and begin the descent.

Each rosette cast was usually lowered to within 5-10 meters of the bottom.

Recovering the package at the end of the deployment was essentially the reverse of launching. Minor exterior freezing of the sample valve tips and dripping water from the frame were observed on casts where air temperature was below -6°C. The rosette was moved into the CTD container for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

Routine CTD maintenance included rinsing the sensors, carousel, and frame with fresh water between casts. Due to the potential for freezing, fresh water was not kept in the sensor lines between casts. Rosette maintenance was performed on a regular basis. O-rings were regularly inspected and changed as necessary, and bottle maintenance was performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired as needed. A few ball valves had to be replaced with spigots when they were broken off during rosette recoveries.

1.2. Underwater Electronics Packages

CTD data were collected with a SBE9*plus* CTD (STS #727). The instrument provided channels with pressure, dual temperature (SBE3*plus*), dual conductivity (SBE4C), dissolved oxygen (SBE43), transmissometer (Wetlabs C-Star), two fluorometers (Seapoint for chlorophyll a, Haardt for CDOM) and altimeter (Simrad 807 or Benthos 916D). The CTD supplied a standard Sea-Bird format data stream at a data rate of 24 frames/second (fps).

Sea-Bird SBE32 36-place Carousel Water Sampler	S/N 3213290-0113
Sea-Bird SBE35RT Digital Reversing Thermometer	S/N 3528706-0035
Sea-Bird SBE9*plus* CTD	S/N 09P31807-0727
Paroscientific Digiquartz Pressure Sensor	S/N 90577
Sea-Bird SBE3*plus* Temperature Sensor	S/N 03P-2202 (Primary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2113 (Primary)
Sea-Bird SBE43 DO Sensor	S/N 43-0244 (stations 1-25)
Sea-Bird SBE43 DO Sensor	S/N 43-0185 (stations 26-)
Sea-Bird SBE3*plus* Temperature Sensor	S/N 03P-4308 (Secondary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2818 (Secondary, stations 1-25)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-1919 (Secondary, stations 26-)
Wetlabs C-Star Transmissometer	S/N CST-479DR
Seapoint Fluorometer	S/N 2749
Haardt Fluorometer	S/N 12030 (TAMU/Galveston)
Simrad 807 Altimeter	S/N 4051 (stations 1-41)
Benthos 916D Altimeter	S/N 850 (stations 42-)
RDI Broadband 150khz LADCP	S/N xxx (stations 1-17)
RDI Broadband 150khz LADCP	S/N xxx (stations 19-)
LADCP Battery Pack	

Table 1.2.0 AOS-2005 Rosette Underwater Electronics.

The CTD was outfitted with dual pumps. Primary temperature, conductivity and dissolved oxygen were plumbed on one pump circuit, and secondary temperature and conductivity on the other. The CTD and sensors were deployed in a vertical orientation. The primary temperature and conductivity sensors (T1 #03P-4213 and C1 #04-2659) were used for reported CTD temperatures and conductivities on all casts. The secondary temperature and conductivity sensors were used for calibration checks.

The SBE9*plus* CTD and the SBE35RT Digital Reversing Thermometer were both connected to the SBE32 36-place pylon providing for single-conductor sea cable operation. A custom-built 6000m-long 8.15mm cable with two coaxial conductors was used to connect the underwater package to the SBE11*plus* deck unit in the CTD container control station. The center, stranded 20 AWG conductor was used for signal and power. The outer, coaxially wrapped conductor was used for signal and power return. The armor served only as the strength member. Power to the SBE9*plus* CTD (and sensors), SBE32 pylon, SBE35RT and altimeter was provided through the sea cable by the SBE11*plus* deck unit.

1.3. Navigation and Bathymetry Data Acquisition

Navigation data were acquired by one of the Linux workstations beginning 21 August 2005 (UTC) from a Garmin GPS-17 unit mounted on top of the rosette container. Date, time, Position, speed and course were acquired at 1-second intervals.

Very intermittent bathymetry data were available from the Oden's echosounder via the ship's webserver. The bridge provided approximate charted depths as available at cast time; when the Healy was nearby, Seabeam data were used to estimate bottom depths.

1.4. Real-Time CTD Data Acquisition System

The CTD data acquisition system consisted of an SBE-11*plus* deck unit and three networked generic PC workstations running Fedora 2 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball, 120 GB disk, and DVD+RW drives. Two systems shared a single display, keyboard and trackball due to limited space in the cast control room. One of the systems also had 8 additional RS-232 ports via a Rocketport PCI serial controller. The systems were networked through a 100BaseTX ethernet switch, which was also connected to the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management and backup. Hardcopy capability was provided by an HP Officejet d155xi network printer.

One of the workstations was designated the CTD console and was connected to the CTD deck unit via RS-232. The CTD console provided an interface for controlling CTD deployments as well as real-time operational displays for CTD and rosette trip data, GPS navigation, and bathymetry when available from the Oden displays or Healy Seabeam website.

CTD deployments were initiated by the console watch after the ship stopped on station. The watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any pertinent comments. The deployment software presented a short dialog instructing the operator to turn on the deck unit, to examine the on screen raw data display for stable CTD data, and to notify the deck watch that this was accomplished. When the deck watch was ready to put the rosette over the side, the console watch was notified and the CTD data acquisition started. The deployment software display changed to indicate that a cast was in progress. A processed data display appeared, as did a rosette bottle trip display and control for closing bottles. Various real-time plots were initiated to display the progress of the deployment. GPS time and position were automatically logged at 1 second resolution during the cast. Both raw and processed (2 Hz time-series) CTD data were automatically backed up by one of the other workstations via ethernet.

Once the deck watch had deployed the rosette, the winch operator immediately lowered it to 10-15 meters. The CTD pumps were configured with an 8 second startup delay, and were on by the time the rosette reached 10 meters. The console operator checked the CTD data for proper sensor operation, then instructed the winch operator to bring the package to the surface and descend to a target depth (wire-out). The lowering rate was normally 60-65 meters/minute for this package.

The console watch monitored the progress of the deployment and quality of the CTD data through interactive graphics and operational displays. Additionally, the watch decided where to trip bottles on the up cast, noting this on the console log. The altimeter channel, CTD depth and wire-out were monitored to determine the distance of the package from the bottom. The on-screen winch and altimeter displays allowed the watch to refine the target wire-out relayed to the winch operator and safely approach to within 10 meters of the bottom.

Bottles were closed on the upcast by operating a "point and click" graphical trip control button. The data acquisition system responded with trip confirmation messages and the corresponding CTD data in a rosette bottle trip window on the display. All tripping attempts were noted on the console log. The console watch then directed the winch operator to raise the package up to the next bottle trip location. The console watch was also responsible for creating a sample log for the deployment which was used to record the correspondence between rosette bottles and analytical samples taken.

After the last bottle was tripped, the console watch directed the deck watch to bring the rosette on deck. Once on deck, the console watch terminated the data acquisition, turned off the deck unit and assisted with rosette sampling.

1.5. CTD Data Processing

ODF CTD processing software consists of over 30 programs running in a Linux/Unix run-time environment.

Raw CTD data are initially converted to engineering units, filtered, response-corrected, calibrated and decimated to a more manageable 0.5 second time-series. The laboratory calibrations for pressure, temperature and conductivity are applied at this time.

Once the CTD data are reduced to a standard format time-series, they can be manipulated in various ways. Channels can be additionally filtered. The time-series can be split up into shorter time-series or pasted together to form longer time-series. A time-series can be transformed into a pressure-series, or into a larger-interval time-series. Adjustments to pressure, temperature and conductivity determined from comparisons to other sensors and to check samples are maintained in separate files and are applied whenever the data are accessed.

The CTD data acquisition software acquired and processed the data in real-time, providing calibrated, processed data for interactive plotting and reporting during a cast. The 24 Hz CTD data were filtered, response-corrected and decimated to a 2 Hz time-series. Sensor correction and calibration models were applied to pressure, temperature, and conductivity. Rosette trip data were extracted from this time-series in response to trip initiation and confirmation signals. All data were stored on disk and were additionally backed up via ethernet to a second system. At the end of the cast, various consistency and calibration checks were performed and a 2 db pressure-series of the down cast was generated and subsequently used for reports and plots.

CTD data were examined at the completion of deployment for potential problems. Data from the two CTD temperature sensors were examined, compared with SBE35RT Digital Reversing Thermometer data and checked for sensor drift. CTD conductivity sensors were compared and calibrated by examining differences between CTD and check-sample conductivity values. The CTD dissolved oxygen sensor data were calibrated to check-sample data. Additionally, deep theta-salinity and theta-O_2 comparisons were made between down and up casts as well as with adjacent deployments.

The initial 10-meter yoyo in each deployment, where the package was lowered and then raised back to the surface to start the SBE pumps, was omitted during the generation of the 2 db pressure-series.

Density inversions can be induced in high-gradient regions by ship-generated vertical motion of the rosette. Detailed examination of the raw data shows significant mixing can occur in these areas because of "ship roll". To minimize density inversions, a "ship-roll" filter which disallowed pressure reversals was applied during the generation of the 2 db pressure-series down-cast data.

The sensors were exposed to below-freezing air temperatures during the last few stations. Water in the pump tubes near the sensors at least partially froze before the casts at stations 108 and 109. The pump tubes were cleared with warm water prior to deployment, and none of the sensors appear to have been adversely affected.

Two CTD casts are reported for stations 9, 31, 61 and 93. The rosette was lowered to approximately 250m on the first cast at each station to collect water for CDOM only. These shallow casts were not processed beyond the initial block-averaging and automated post-cast processing. The second cast reported at each of these stations was the standard deep cast.

1.6. CTD Laboratory Calibration Procedures

Laboratory calibrations of the CTD pressure, temperature and conductivity sensors were used to generate Sea-Bird conversion equation coefficients applied by the data acquisition software at sea.

CTD #381 with pressure transducer #58952 was used for P16S-2005.

Pressure calibrations were last performed on CTD #381 at the ODF Calibration Facility (La Jolla) on 16 November 2004. The Paroscientific Digiquartz pressure transducer was calibrated in a temperature-controlled water bath to a Ruska Model 2400 Piston Gauge Pressure Reference.

The SBE3*plus* temperature sensors (primary S/N 03P-4213, secondary S/N 03P-4226) were calibrated at ODF on 16 November 2004.

The primary and secondary SBE4 conductivity sensors (S/N 04-2659 and S/N 04-2319) were both calibrated on 16 November 2004 at SBE.

The SBE35RT Digital Reversing Thermometer (S/N 35-0035) was calibrated on 15 September 2004 at ODF.

1.7. CTD Shipboard Calibration Procedures

CTD #381 was used for all AOS-2005 casts. The CTD was deployed with all sensors and pumps aligned vertically, as recommended by SBE. Secondary temperature and conductivity (T2 & C2) sensors served as calibration checks for the reported primary temperature and conductivity (T1 & C1) on all casts. The SBE35RT Digital Reversing Thermometer (S/N 35-0035) served as an independent temperature calibration check. *In-situ* salinity check samples collected during each CTD cast were used to calibrate the conductivity sensors.

1.7.1. CTD Pressure

Pressure sensor conversion equation coefficients derived from the pre-cruise pressure calibration for CTD #381 (Pressure S/N 58952) were applied to raw pressure data during each cast. Out-of-water pressure values were running 1.0-1.2 decibars at cast start, and 0.6-0.7 decibars at cast end. The pressure was offset by -0.7 decibars at the surface, sloping to 0 correction at 5000 decibars, for stations 1-57. After air and sea-surface temperatures cooled off, the offset was reduced to -0.5 decibars at the surface (sloping to 0 at 5000 decibars) for stations 58-87, and to -0.3 decibars at the surface (sloping to 0 at 3000 decibars) for stations 88-111.

Start and end pressures were tabulated for each cast to check for calibration shifts. The start pressures were between 0 and 0.6 decibars, and the end pressures were between 0 and -0.2 decibars.

The post-cruise CTD #381 pressure calibration results are pending.

1.7.2. CTD Temperature

Temperature sensor conversion equation coefficients were derived from the pre-cruise calibrations and applied to raw primary and secondary temperature data. The primary (T1, S/N 03P-4213) and secondary (T2, S/N 03P-4226) SBE3*plus* temperature sensors were used the entire cruise without replacement.

Two independent metrics of calibration accuracy were examined. The primary and secondary temperatures were compared at each rosette trip, and the SBE35RT (S/N 35-0035) temperatures were compared to primary and secondary temperatures at each rosette trip.

The T1 sensor appeared to have a slow, steady drift with station number, relative to the SBE35RT: +0.5 to +1.0 mdegC from stations 1-111. The T2 sensor was less stable, starting 1.0 mdeg.C high, drifting to 0, then back to 0.8 mdeg.C high. The sensor calibration histories were examined, and the SBE35RT was deemed most likely of the 3 to be correct. Offsets were calculated from SBE35RT-T1 differences, using data below 1500 decibars. The offsets, shifting slightly for each station, were applied to T1 data. There did not appear to be any residual pressure effect on the T1 or SBE35 sensors. The T2 sensor was not corrected.

Figures 1.7.2.0 and 1.7.2.1 show T1-T2 residual differences after shipboard correction of T1 only. The shipboard-final T1 and SBE35RT comparisons are summarized in figures 1.7.2.2 and 1.7.2.3.

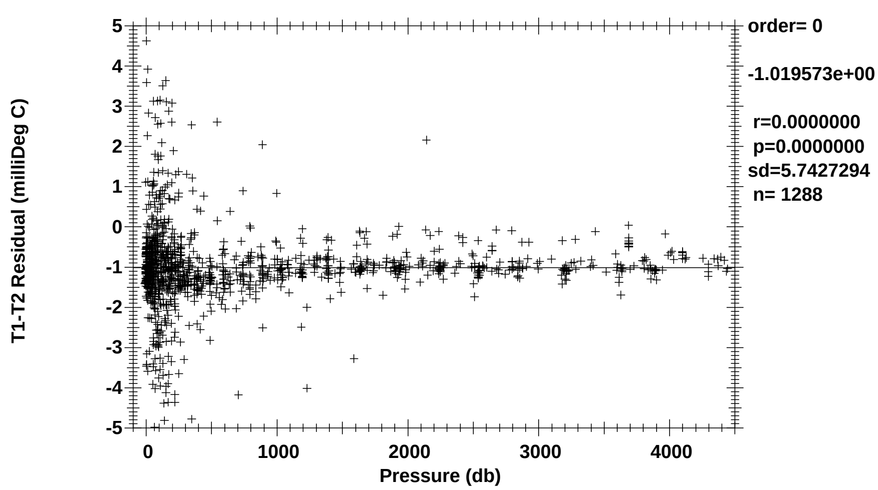

Figure 1.7.2.0 Primary and secondary temperature differences by pressure, all pressures.

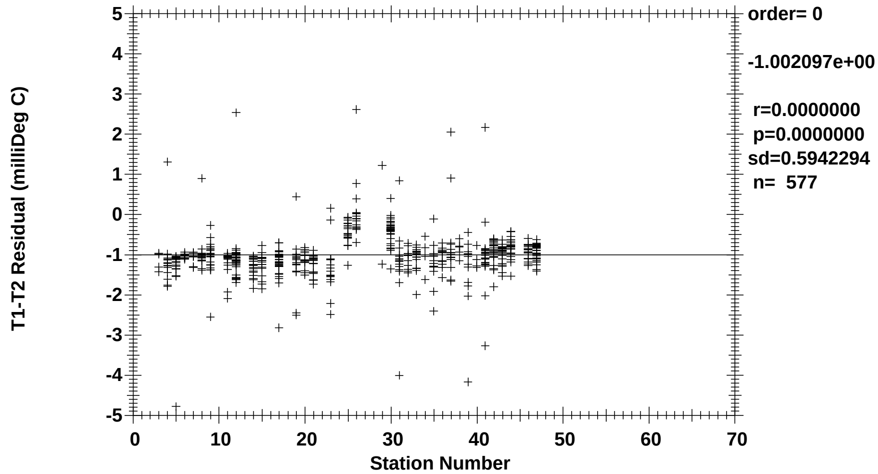

Figure 1.7.2.1 Primary and secondary temperature differences by cast, p>1000db.

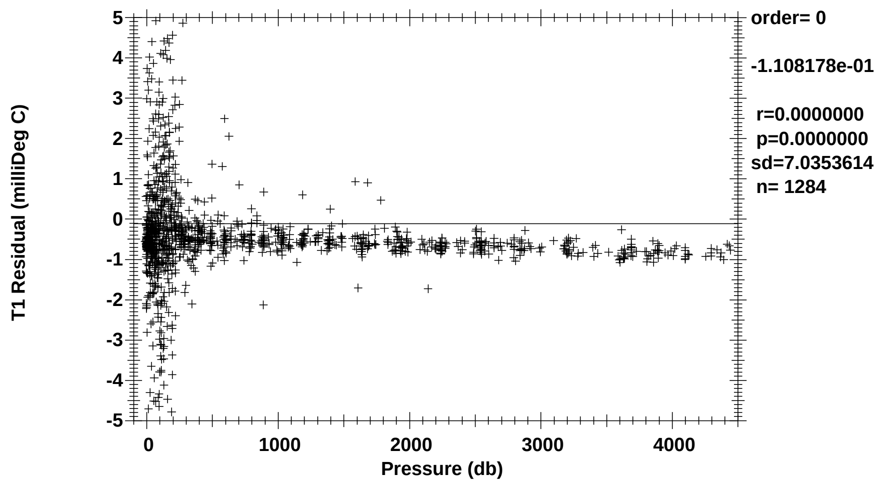

Figure 1.7.2.2 T1 and SBE35RT temperature differences by pressure, all pressures.

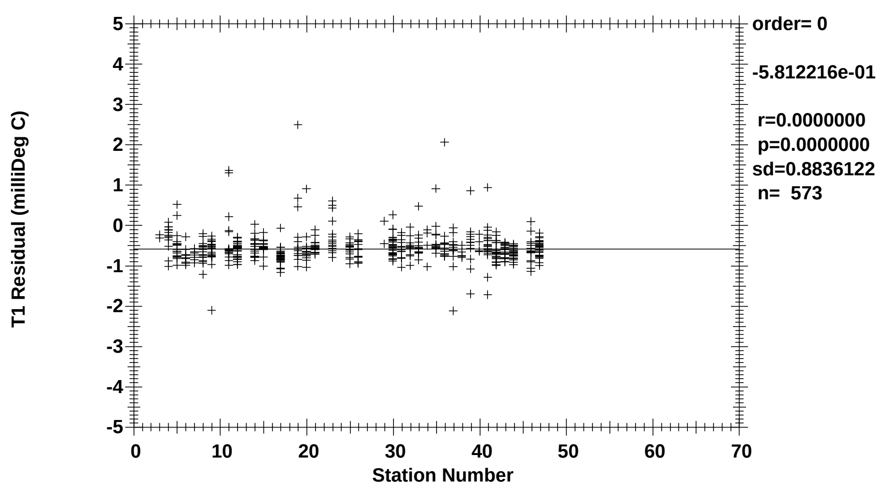

Figure 1.7.2.3 T1 and SBE35RT temperature differences by cast, p>1000db.

Post-cruise calibrations for all the temperature sensors are pending.

1.7.3. CTD Conductivity

Conductivity sensor conversion equation coefficients were derived from the pre-cruise calibrations and applied to raw primary and secondary conductivities.

The same primary (C1 - S/N 04-2659) and secondary (C2 - S/N 04-2319) SBE4 conductivity sensors were used on all of AOS-2005 . C1 was used for all reported CTD conductivities; C2 was used as a calibration check on the primary sensor.

Comparisons between the primary and secondary sensors, and between sensors and check sample conductivities, were used to derive conductivity sensor corrections. The average C1-C2 differences were about +0.001 mS/cm at the start of the cruise, increased to +0.0015 by station 25, then dropped to +0.0005 by station 40. The differences abruptly shifted at station 50, after the sensors were cleaned with Triton X (according to SBE specs). After a few more stations, the averages stabilized a bit, varying between +0.001 and +0.0015 mS/cm for the rest of the cruise. Another cleaning with Triton X between stations 92 and 93 appeared to have no effect on either C1 or C2 data. The bottle-C1 average values were less consistent, and varied more than 0.002 mS/cm.

The differences between sensors and bottles were considered at the same time as deep theta-salinity overlays of consecutive stations were examined for both T1C1 and T2C2 sensor pairs. C1 offsets were adjusted by as much as ±0.0005 mS/cm for a few casts to provide deep theta-salinity consistency, and had the effect of "normalizing" some of the differences between sensors and bottle data. A second-order pressure-dependent slope was fit to the adjusted bottle-C1 differences, omitting stations 1-20 to eliminate any possibility of residual Autosal suppression issues at the shallow end. The resulting correction (on the order of +0.001 mS/cm at 0 decibars, -0.001 mS/cm at 3500 decibars and -0.0006 mS/cm at 5700 decibars) was applied to all C1 data. C2 data were not corrected.

Shipboard overlays of deep theta-salinity profiles were checked for cast-to-cast consistency after the corrections were applied. Stations 50-74 (after the first Triton X cleaning) were adjusted slightly, to better align the profiles and the bottle-C1 differences. Most deep profiles of adjacent casts agreed to within ±0.0001-2 mS/cm.

The comparison of the primary and secondary conductivity sensors by station, after applying shipboard corrections, is summarized in figure 1.7.3.0.

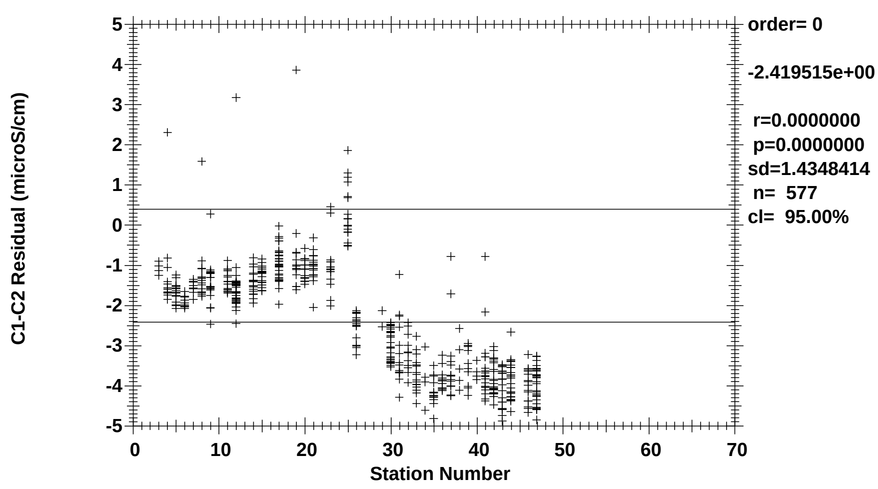

Figure 1.7.3.0 C1 and C2 conductivity differences by cast, p>1000db.

Salinity residuals after applying shipboard T1/C1 corrections are summarized in figures 1.7.3.1 through 1.7.3.3.

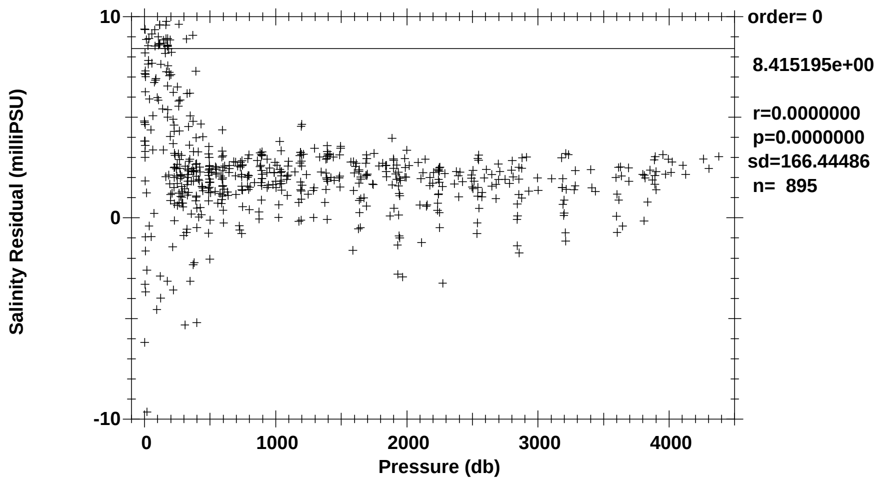

Figure 1.7.3.1 salinity residuals by pressure, all pressures.

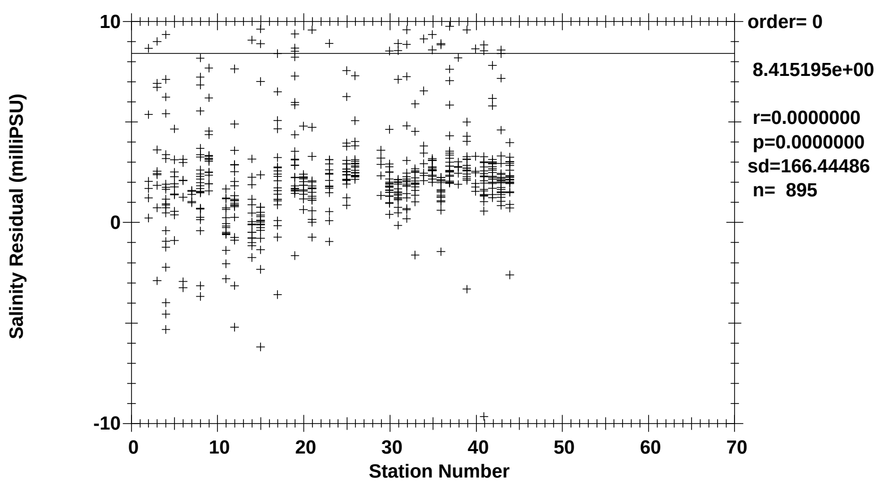

Figure 1.7.3.2 salinity residuals by cast, all pressures.

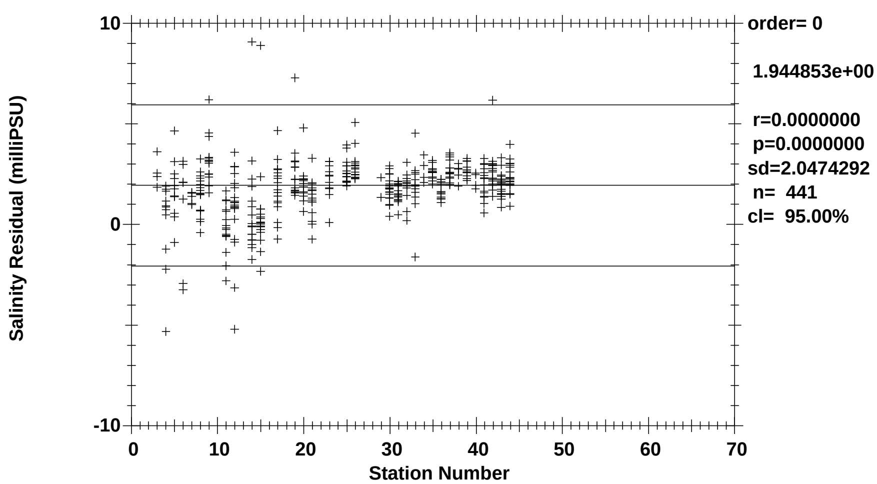

Figure 1.7.3.3 salinity residuals by cast, p>1000db.

Figure 1.7.3.3 represents an estimate of the deep salinity accuracy for the CTD/sensors used during P16S-2005. The 95% confidence limit is ±0.0018 PSU relative to bottle salts.

Post-cruise calibrations of the conductivity sensors by Sea-Bird are pending. These calibrations will not account for any pressure effects on the sensors.

1.7.4. CTD Dissolved Oxygen

Two SBE43 dissolved O_2 (DO) sensor were used during this cruise: S/N 43-0275 for stations 1-11 and 43-0185 for stations 12-111. The sensor was plumbed into the P/T1/C1 intake line in a vertical configuration after C1 and before P1 (as specified by SBE).

The first DO sensor (43-0275) offset and cut out repeatedly during station 1. The cable between the CTD and sensor was replaced before station 2. A cursory check of data during the next few casts showed that problem to be fixed, but the sensor apparently had other major problems. Its sensitivity decreased rapidly for the next few stations, until the raw signal was low and shapeless by station 11. The CTD oxygen data for stations 1 and 11 were deemed unusable and are not reported. For the casts in between, only stations 5 and 6 somewhat fit the bottle data from surface to bottom. Because of the poor fits and obvious problems with the sensor, stations 2-10 CTD oxygen data are reported, but all coded questionable or bad.

The second sensor (43-0185) was installed prior to station 12 and performed reliably for the rest of the cruise. Standard and blank values for bottle oxygen data were smoothed and applied prior to fitting the CTD oxygen profiles.

The DO sensor calibration method used for this cruise was to match down-cast CTD O_2 data to up-cast bottle trips along isopycnal surfaces, then to minimize the residual differences between the *in-situ* check sample values and CTD O_2 using a non-linear least-squares fitting procedure. Since this technique only calibrates the down-cast, only the 2 db pressure series down-cast data contain calibrated CTD O_2.

The coefficients for the deep casts were used for the shallow casts on the four 250m "CDOM" casts (9/1, 31/1, 61/2 and 93/1), which had no bottle data; the CTD oxygen for those shallow casts are reported as uncalibrated.

Figures 1.7.4.0, 1.7.4.1 and 1.7.4.2 show the residual differences between bottle and calibrated CTD O_2 for all pressures where both CTD and bottle oxygen data are coded "acceptable". Figure 1.7.4.3 shows the residual differences for pressures deeper than 1000 db.

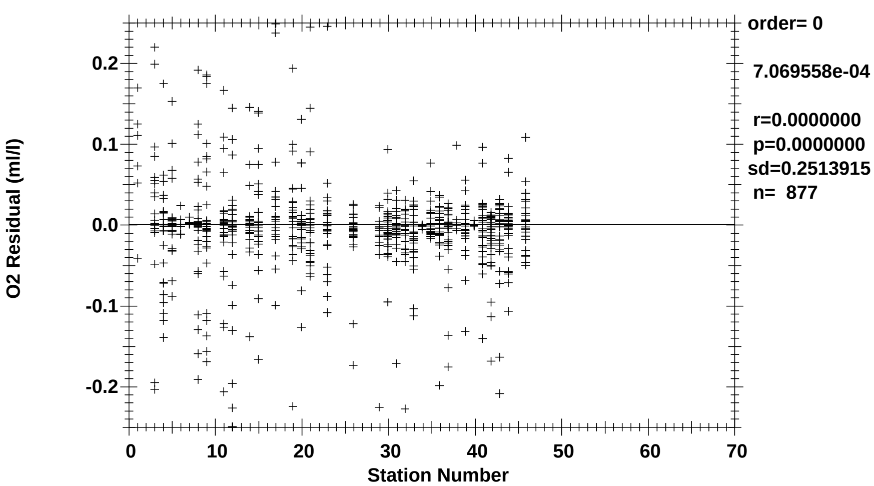

Figure 1.7.4.0 O_2 residuals by station number, all pressures.

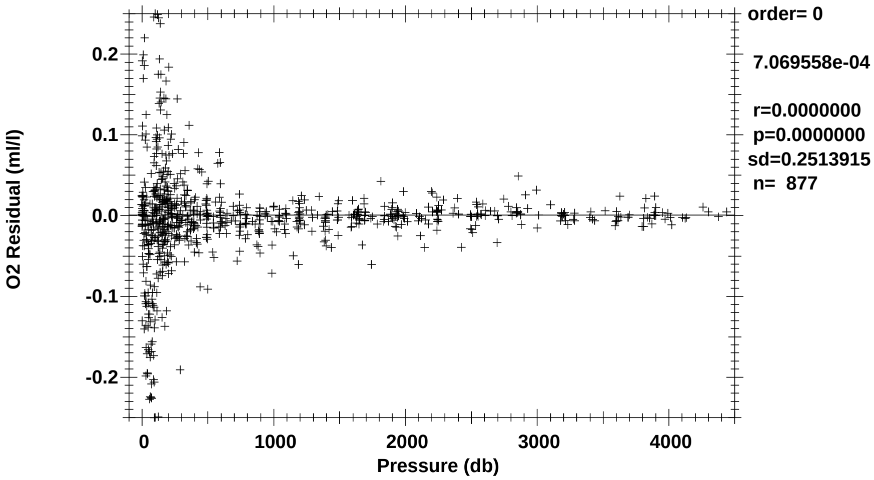

Figure 1.7.4.1 O_2 residuals by pressure, all pressures.

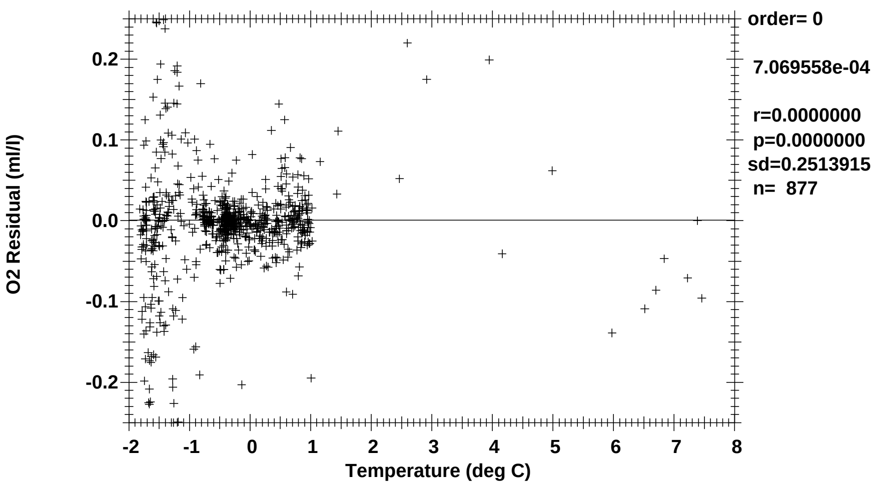

Figure 1.7.4.2 O_2 residuals by temperature, all pressures.

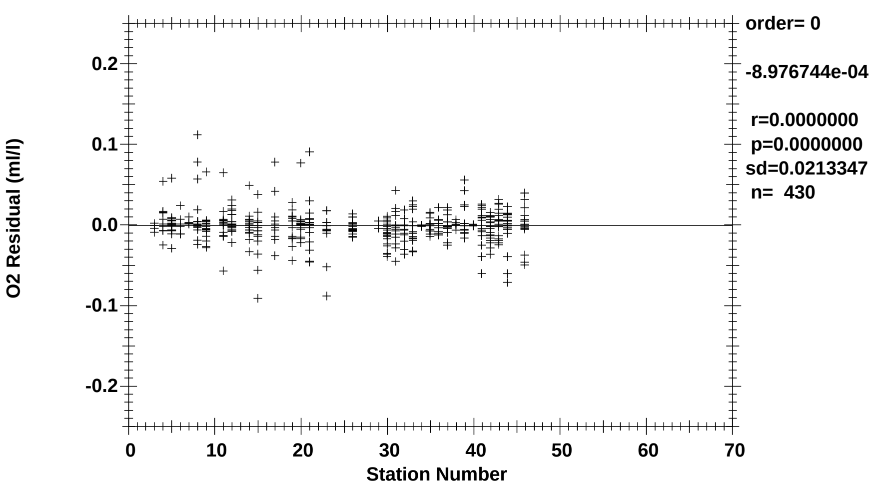

Figure 1.7.4.3 O_2 residuals by station number, p>1000db .

The standard deviations of 0.0574 ml/l for all oxygens and 0.0142 ml/l for deep oxygens are only intended as indicators of how well the up-cast bottle O_2 and down-cast CTD O_2 match. ODF makes no claims regarding the precision or accuracy of CTD dissolved O_2 data.

The general form of the ODF O_2 conversion equation for Clark cells follows Brown and Morrison [Brow78] and Millard [Mill82], [Owen85]. ODF models membrane and sensor temperatures with lagged CTD temperatures and a lagged thermal gradient. *In-situ* pressure and temperature are filtered to match the sensor response. Time-constants for the pressure response τ_p, two temperature responses τ_{Ts} and τ_{Tf}, and thermal gradient response τ_{dT} are fitting parameters. The thermal gradient term is derived by low-pass filtering the difference between the fast response (T_f) and slow response (T_s) temperatures. This term is SBE43-specific and corrects a non-linearity introduced by analog thermal compensation in the sensor. The O_c gradient, dO_c/dt, is approximated by low-pass filtering 1st-order O_c differences. This gradient term attempts to correct for reduction of species other than O_2 at the sensor cathode. The time-constant for this filter, τ_{og}, is a fitting parameter. Dissolved O_2 concentration is then calculated:

$$O_{2ml/l} = [c_1 O_c + c_2] \cdot f_{sat}(S,T,P) \cdot e^{(c_3 P_l + c_4 T_f + c_5 T_s + c_6 \frac{dO_c}{dt} + c_7 dT)} \qquad (1.7.4.0)$$

where:

$O_{2ml/l}$	= Dissolved O_2 concentration in ml/l;
O_c	= Sensor current (μamps);
$f_{sat}(S,T,P)$	= O_2 saturation concentration at S,T,P (ml/l);
S	= Salinity at O_2 response-time (PSUs);
T	= Temperature at O_2 response-time (°C);
P	= Pressure at O_2 response-time (decibars);
P_l	= Low-pass filtered pressure (decibars);
T_f	= Fast low-pass filtered temperature (°C);
T_s	= Slow low-pass filtered temperature (°C);
$\frac{dO_c}{dt}$	= Sensor current gradient (μamps/secs);
dT	= low-pass filtered thermal gradient (T_f - T_s).

1.8. Bottle Sampling

At the end of each rosette deployment water samples were drawn from the bottles in the following order (not enforced after DIC/TAlk/pH drawn):

- CFCs
- Halocarbons
- SF_6
- ^{3}He
- O_2
- Mercury
- Dissolved Inorganic Carbon (DIC)/Total Alkalinity/pH
- Nutrients
- ^{129}I
- Dissolved Organic Material (DOM) - small volume
- ^{3}H
- $\delta^{18}O$
- Salinity
- Dissolved Organic Material (DOM) - large volume
- POP
- Muir
- Triple-O Isotopes ($^{16}O/^{17}O/^{18}O$)
- ^{14}C
- Biology
- ^{226}Ra

The correspondence between individual sample containers and the rosette bottle from which the sample was drawn was recorded on the sample log for the cast. Additionally, unique BIO numbers assigned to each station-cast-bottle combination were recorded, and BIO stickers duplicating those attached to Niskin bottles prior to each cast were placed on sampling containers to clarify its water source. The sample log also included any observations and comments about the condition of the rosette and bottles. One member of the sampling team was designated the *sample cop*, whose sole responsibility was to maintain this log and insure that sampling progressed in the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation and other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity were routinely noted on the sample log. Drawing oxygen samples also involved taking the sample draw temperature from the bottle. The temperature was noted on the sample log and could be useful in determining leaking or mis-tripped bottles.

Once individual samples had been drawn and properly prepared, they were distributed for analysis. Oxygen, nutrient and salinity analyses were performed on computer-assisted (PC) analytical equipment networked to the data processing computer for centralized data management.

1.9. Bottle Data Processing

Water samples collected and properties analyzed shipboard were managed centrally in a relational database (PostgreSQL-7.4.7-3) run on one of the Linux workstations. A web service (OpenACS-5.1.5 and AOLserver-4.0.10-1) front-end provided ship-wide access to CTD and water sample data. Web-based facilities included on-demand arbitrary property-property plots and vertical sections as well as secure data uploads and downloads.

The Sample Log data and any diagnostic comments were entered into the database once sampling was completed. Quality flags associated with sampled properties were set to indicate that the property had been sampled, and sample container identifications were noted where applicable (e.g. oxygen flask number). Each Sample Log was also scanned and made available as a JPEG file on the website.

Analytical results were provided on a regular basis by the various analytical groups and incorporated into the database. These results included a quality code associated with each measured value and followed the coding scheme developed for the World Ocean Circulation Experiment (WOCE) Hydrographic Programme (WHP) [Joyc94].

Various consistency checks and detailed examination of the data continued throughout the cruise. The comments from the Sample Logs and individual data point checking are included in the Appendix of this documentation.

1.10. Salinity Analysis

Equipment and Techniques

A Guildline Autosal Model 8400A salinometer (S/N 48-263) was used for all salinity measurements. It was first located in van 14 on top of Oden's main lab (stations 1-11), then moved to the main lab clean room for the rest of the cruise to attain better room temperature stability. The salinometer was modified by STS to contain an interface for computer-aided measurement. The water bath temperature was set and maintained at a value near the laboratory air temperature: 27°C for stations 1-11, 14-20 and 38-53 analyses, and 30°C for stations 12 and 21-37.

The salinity analyses were performed after samples had equilibrated to laboratory temperature: within 70-105 hours after collection for the first 15 stations, and within 9-36 hours for later casts, when room temperature stability was not an issue. The salinometer was standardized for each group of analyses (usually 1-2 casts, up to ~38 samples, using one fresh vial of standard seawater at the start of each run and another at the end to determine salinometer drift. Salinometer measurements were made by computer, where the analyst was prompted by software to enter salt and Niskin bottle information, change samples and flush.

Sampling and Data Processing

3699 salinity measurements were made and approximately 70 vials of standard seawater (SSW) were used.

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to insure an airtight seal. The draw time and equilibration time were logged for all casts. Laboratory temperatures were logged at the beginning and end of each run, and monitored throughout the run.

PSS-78 salinity [UNES81] was calculated for each sample from the measured 2X conductivity ratios. The difference (if any) between the initial vial of standard water and the next one run as an unknown was applied as a linear function of elapsed run time to the data. The corrected salinity data were then incorporated into the cruise database. The estimated accuracy of bottle salinities run at sea is usually better than ±0.002 PSU relative to the particular standard seawater batch used. The 95% confidence limit for residual differences between the bottle salinities and calibrated CTD salinity relative to SSW batch P-145 was ±0.0055 PSU for all salinities, and ±0.0018 PSU for salinities deeper than 1000db.

Three adjustments other than bath temperature changes were made to the Autosal. After station 20 salinity was run, it was discovered that the amplifier gain for proper balance between suppression ranges had not been adjusted. This was changed, and stations 1-20 salinities were recalculated. A minor adjustment was made to the Autosal before station 47, and maintenance was performed on the air pump before station 92 was run.

Laboratory Temperature

The air temperature in van 14 varied from 23.0 to 30.5°C for the first 11 stations run. Within a few casts after moving Autosal operations to the clean room, the air temperature range was reduced significantly to 25.5 to 27.2°C, varying by less than ±0.4°C during most runs.

Standards

IAPSO Standard Seawater (SSW) Batch P-145 was used to standardize all salinity measurements.

1.11. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an ODF-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365nm wavelength ultra-violet light. The titration of the samples and the data logging were controlled by PC software. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 ml buret. ODF used a whole-bottle modified-Winkler titration following the technique of Carpenter [Carp65] with modifications by Culberson *et al.* [Culb91], but with higher concentrations of potassium iodate standard (~0.012N) and thiosulfate solution (~55 gm/l). Pre-made liquid potassium iodate standards were run once a day approximately every 4 stations, unless changes were made to system or reagents. Reagent/distilled water blanks were determined every day or more often if a change in reagents required it to account for presence of oxidizing or reducing agents. The auto-titrator performed well.

Sampling and Data Processing

0000 oxygen measurements were made. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Using a Tygon and silicone drawing tube, nominal 125ml volume-calibrated iodine flasks were rinsed 3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. The sample drawing temperatures were measured with a small platinum resistance thermometer embedded in the drawing tube. These temperatures were used to calculate umol/kg concentrations, and as a diagnostic check of bottle integrity. Reagents were added to fix the oxygen before stoppering. The flasks were shaken twice (10-12 inversions) to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 20 minutes.

The samples were analyzed within 12 hours of collection, and the data incorporated into the cruise database.

Thiosulfate normalities were calculated from each standardization and corrected to 20°C. The 20°C normalities and the blanks were plotted versus time and were reviewed for possible problems.

The sample drawing temperature thermometer during this leg was functional and calibrated at the beginning of the expedition.

A noisy endpoint was occasionally acquired during the analyses, usually due to small waterbath contaminations. These endpoints were checked and recalculated using STS/ODF designed software.

The blanks and thiosulfate normalities for each batch of thiosulfate were smoothed (linear fits) in three groups during the cruise and the oxygen values recalculated. There were equipment problems with one of the Dosimat units at the start of the cruise which led to some high oxygen values for a number of samples. The problem was tracked down and corrected.

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water to determine flask volumes at STS/ODF's chemistry laboratory. This is done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The volumetric flasks used in preparing standards were volume-calibrated by the same method, as was the 10 ml Dosimat buret used to dispense standard iodate solution.

Standards

Liquid potassium iodate standards were prepared and bottled in sterile glass bottles at STS/ODF's chemistry laboratory prior to the expedition. The normality of the liquid standard was determined at ODF by calculation from weight. A single standard batch was used during AOS-2005 . Potassium iodate was obtained from Acros Chemical Co. and was reported by the supplier to be >99.4% pure. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

1.12. Nutrient Analysis

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate and nitrite) were performed on an ODF-modified 4-channel Technicon AutoAnalyzer II, generally within one to two hour after sample collection. Occasionally samples were refrigerated up to 12 hours at ~4°C. All samples were brought to room temperature prior to analysis.

The methods used are described by Gordon *et al.* [Gord92]. The analog outputs from each of the four colorimeter channels were digitized and logged automatically by computer (PC) at 2-second intervals.

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67]. An acidic solution of ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. Tartaric acid was also added to impede PO_4 color development. The sample was passed through a 15mm flowcell and the absorbance measured at 660nm.

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For the nitrate analysis, the seawater sample was passed through a cadmium reduction column where nitrate was quantitatively reduced to nitrite. Sulfanilamide was introduced to the sample stream followed by N-(1-naphthyl)ethylenediamine dihydrochloride which coupled to form a red azo dye. The stream was then passed through a 15mm flowcell and the absorbance measured at 540nm. The same technique was employed for nitrite analysis, except the cadmium column was bypassed, and a 50mm flowcell was used for measurement.

Phosphate was analyzed using a modification of the Bernhardt and Wilhelms [Bern67] technique. An acidic solution of ammonium molybdate was added to the sample to produce phosphomolybdic acid, then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The reaction product was heated to ~55°C to enhance color development, then passed through a 50mm flowcell and the absorbance measured at 820nm.

Sampling and Data Processing

0000 nutrient samples taken from the rosette were analyzed. Approximately 80 additional samples taken at 16 ice stations were analyzed by STS/ODF.

Nutrient samples were drawn into 45 ml polypropylene, screw-capped "oak-ridge type" centrifuge tubes. The tubes were cleaned with 10% HCl and rinsed with sample 2-3 times before filling. Standardizations were performed at the beginning and end of each group of analyses (typically one cast, up to 36 samples) with an intermediate concentration mixed nutrient standard prepared prior to each run from a secondary standard in a low-nutrient seawater matrix. The secondary standards were prepared aboard ship by dilution from primary standard solutions. Dry standards were pre-weighed at the laboratory at ODF, and transported to the vessel for dilution to the primary standard. Sets of 7 different standard concentrations were analyzed periodically to determine any deviation from linearity as a function of absorbance for each nutrient analysis. A correction for non-linearity was applied to the final nutrient concentrations when necessary. A correction for the difference in refractive indices of pure distilled water and seawater was periodically determined and applied where necessary. The pump tubing was changed once.

After each group of samples was analyzed, the raw data file was processed to produce another file of response factors, baseline values, and absorbances. Computer-produced absorbance readings were checked for accuracy against values taken from a strip chart recording. The data were then added to the cruise database.

Nutrients, reported in micromoles per kilogram, were converted from micromoles per liter by dividing by sample density calculated at 1 atm pressure (0 db), *in situ* salinity, and a per-analysis measured laboratory temperature.

Standards

Primary standards for silicate (Na_2SiF_6) and nitrite ($NaNO_2$) were obtained from Johnson Matthey Chemical Co.; the supplier reported purities of >98% and 97%, respectively. Primary standards for nitrate (KNO_3) and phosphate (KH_2PO_4) were obtained from Fisher Chemical Co.; the supplier reported purities of 99.999% and 99.999%, respectively. The efficiency of the cadmium column used for nitrate was monitored throughout the cruise and ranged from 96-100%.

No major problems were encountered with the measurements.

Transient tracer measurements:

The chlorofluorocarbons CFC-12, CFC-11, CFC-113 and the halogenated tracers CH3CCl3 and CCl4 were measured on a purge and trap GC/ECD system. A volume of 31 mL water were injected on to the purge and trap unit, where the samples were purged for five minutes with nitrogen at a flow rate of 80 mL/min. The components were trapped in an open bore 1/16" trap cooled to low temperatures in the headspace immediately over liquid nitrogen. The analytes were thermally desorbed at 100 °C and injected onto a DB624 column (75 m x 0.53 mm). The precision for CFC-12 is estimated to 2 %, and the limit of detection to 0.02 pmol/kg.

Determination of SF6 was performed by purge and trap coupled to gas chromatography with electron capture detection (GC/ECD). A volume 356 mL of seawater was injected into an evacuated strip tower and subsequently purged with nitrogen for 5 minutes at 100 mL/min. The SF6 was trapped in a 1/16", large ID Carboxen-1000 cold trap kept at -60 °C. The sample was thermally desorbed and injected onto a MS 5A column (3 m x 1/8") and then refocused on a 1/32" Carboxen-1000 packed trap kept at -130 °C, from where it is thermally desorbed onto a Porabond Q PLOT column (0.32 mm ID X 30m) kept isothermally at 100 °C. The analytical precision of the method was estimated to 2 % and the detection limit is estimated to 0.1 fmol kg-1. The samples were calibrated vs. calibrated air obtained from CMDL/NOAA, Boulder Colorado, and are reported on the GMD2000 scale.

From Station 26, the supply of Liquid Nitrogen necessary for cooling the traps of both analytical instruments was exhausted. The methods was changes as described below.

For the CFCs a 30cm long trap was filled with Porapak-N was used at temperatures of -26°C using a glycol bath. Only the chlorofluorocarbons: CFC-12, CFC-11, CFC-113 were successfully recovered by this method.

For SF6, the trap was changed to a single 1/8" trap with carboxen-1000 kept at -10°C. The SF6 measurements after station 26 are of lesser quality due to peak broadening.

References

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Data Processing Notes

Date	Contact	Data Type	Event/Summary
2008-04-01	Tanhua, Toste	CFCs/SF6	Submitted; NonPublic
	P.I. is Leif Anderson, Göteborg Data contributor, Toste Tanhua		
2009-09-01	Muus, Dave	BTL/CTD	Website Update; Data online
	ODEN2005 bottle and CTD data notes EXPOCODE 77DN20050819 1 Sept 2009 D. Muus 1. Original bottle taken from STS/ODF aos-2005.hyd and aos-2005.sum received Jan 21, 2006.Changed SAMPNO to BIONBR since Tanhua data has no BTLNBR or SAMPNO; just STNNBR and BIONBR. 2. Updated CFC and SF6 data, Beringia_tracer_20080401.xls, received from Toste Tanhua April 1, 2008. Some samples have values = NaN but flags = 4 or 3. Changed flags to 5. 3. Message from Leif Anderson received Sept 30, 2009, saying data public. 4. Lignin data received from Rainer Amon Apr 23, 2008, not yet included. Need parameter and units mnemonics. 5. PH not yet converted to new parameter names. Now is PH with units @15DEGC. Will change to PH_TOT or PH_SWS with PH_TEMP data all 15.00 DEG C when appropriate parameter determined. 7. DGM, Dissolved Gaseous Mercury, on ODF WOCE format file with units PGRAM/L is not on CCHDO parameter list so is not in exchange bottle file. 8. CTD data from ODF: STS:/cruise/AOS-2005/Hydro/WHP copied 090827/dm		
2009-09-01	Diggs, Steve	BOT/CTD	Website Update; Cruise track plot online
	Cruise track plots made and online. NetCDF files made from Exchange bottle and CTD files, checked and onlne		
2009-09-04	Muus, Dave	PH	Website Update; changed headers
	Notes on modification of ODEN 2005 bottle data EXPOCODE 77DN20050819 Sept 4, 2009 D.Muus 1. Corrected Toste Tanhua email address in Exchange File header to ttanhua@ifm-geomar.de . 2. Changed parameter PH to PH_SWS per R. Key message Sept 2, 2009. 3. Added new column PH_TMP with all values 15 DEG C. 4. NetCDF bottle file, 77DN20050819_nc_hyd.zip, does not yet have above corrections.		